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Growth of Wild Subyearling Fall Chinook Salmon in the Snake River

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Abstract.—Growth is an important determinant of life history development for juvenile anadromous salmonids. We collected juvenile fall chinook salmon *Oncorhynchus tshawytscha* in two reaches of the Snake River to describe growth in fork length (mm/d) and to test for a relation between growth and water temperature. Growth rate during shoreline rearing was significantly higher (P = 0.003) for parr in the warmer of these two reaches (grand means = 1.2 ± 0.04 and 1.0 ± 0.04 mm/d). Because smolts from the two reaches share a common, relatively warm downstream migration route, growth rates were similar between smolts from the two reaches (P = 0.18; grand means = 1.3 ± 0.04 and 1.4 ± 0.04 mm/d). By pooling data across reaches and life stages, we found that growth rate generally increased as water temperature increased (N = 17, r^2 = 0.62, P = 0.0002). The growth rates we observed were probably lower than for fall chinook salmon in a historical rearing area now inaccessible because of dams, but they were still rapid by comparison with those reported for ocean-type chinook salmon in presumably more productive brackish and saltwater habitats. We suggest that growth could be used as an index of the possible negative effects of hatchery supplementation or water management actions that decrease temperature during seaward migration.

The level of growth sustained by young, anad-

migrate seaward as subyearlings (an ocean-type life history; Healey 1991; Taylor 1990).

The majority of wild, ocean-type chinook salmon that inhabit the Snake River from the Hells Canyon Dam to the upper end of Lower Granite Reservoir (Figure 1) are fall chinook salmon that migrate seaward as subyearlings during spring and summer (Marshall et al. 2000; Connor et al. 2001a). A small number of the offspring of wild, stream-type spring and summer chinook salmon disperse long distances from natal streams into the Snake River where they rear, grow rapidly, and then migrate seaward 1 year earlier than normal (Connor et al. 2001a, 2001b). For simplicity, we refer to the wild, subyearling chinook salmon that inhabit the shorelines of the Snake River during spring and summer as fall chinook salmon.

The upper reach (Figure 1) of the Snake River is warmer than the lower reach during winter through spring when fall chinook salmon eggs are incubating, and during spring when juveniles are rearing and starting seaward movement (Connor et al. 2002). Consequently, the life history of young fall chinook salmon progresses on an earlier time schedule in the upper reach of the Snake River than in the lower reach. Assuming life stage pro-

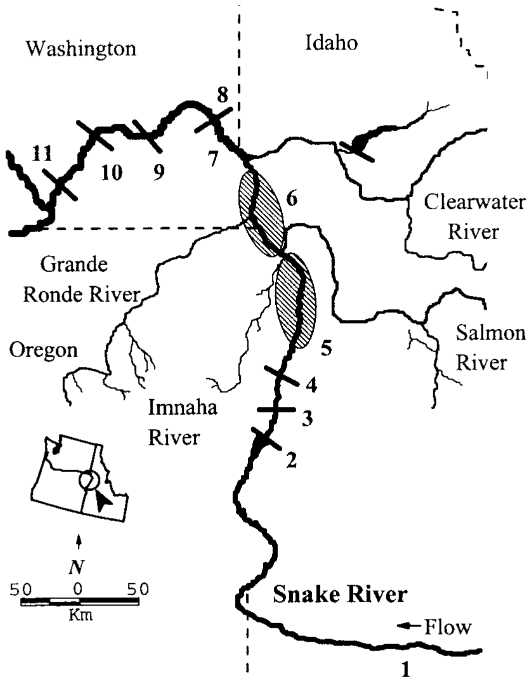

FIGURE 1.—Locations of the upper and lower reaches of the Snake River where adult fall chinook salmon spawn and their offspring were captured by using a beach seine (cross hatched ellipses), and Lower Granite and Little Goose dams and reservoirs. The locations are as follows: 1 = the historical spawning and rearing area near Marsing, Idaho; 2 = Brownlee Dam; 3 = Oxbow Dam; 4 = Hells Canyon Dam; 5 = Snake River upper reach; 6 = Snake River lower reach; 7 = Lower Granite Reservoir; 8 = Lower Granite Dam; 9 = Little Goose Dam; 10 = Lower Monumental Dam; and 11 = Ice Harbor Dam.

mouth. Thermographs were typically stationed offshore in relatively deep water to ensure submergence at all flow levels. Thermograph locations in the Snake River varied by year and flow level. Data were collected at rkm 383, rkm 369, rkm 325, and rkm 303 in the upper reach of the Snake River, and at rkm 290, rkm 287, rkm 274, rkm 265, and rkm 251 in the lower reach of the Snake River. No temperature data were available for the lower reach of the Snake River in 1996 or for either reach in 2000 because of thermograph failure.

The daily mean water temperature was calculated from thermograph output. Data for two or more thermographs in the Snake River were averaged within a reach to provide one daily mean water temperature value. Missing daily mean values were predicted by using ordinary least-squares regression (r^2 = 0.94–0.99). For example, missing daily mean values were predicted for 30 June to 7 July 1999 by using a regression model fit from the observed day of the year (e.g., 1 January = 1) and daily mean water temperatures collected 3 weeks before 30 June and 3 weeks after 7 July 1999.

Daily mean water temperature data were also collected in the tailrace of Lower Granite Dam (Figure 1) from 1995 to 1998 (U. S. Army Corps of Engineers, Walla Walla District, unpublished data). We used data collected in the forebay of Lower Granite Dam when tailrace data were unavailable.

Two water temperature indices were calculated from the daily mean water temperature data. Mean spring (20 March to 20 June) water temperatures in each reach of the Snake River were used as an index of growth conditions during shoreline rearing. Mean spring–summer (20 March to 21 September) water temperatures at Lower Granite Dam were used as an index of growth conditions during seaward migration.

Growth.—Fall chinook salmon were captured in the upper and lower reaches of the Snake River from 1992 to 2000 (Connor et al. 2002). We analyzed data collected on fall chinook salmon from 1995 to 2000 because data sets were complete for both the upper and lower reaches of the Snake River. Sampling was conducted using a beach seine (Connor et al. 1998). Beach seining typically started in April soon after fry began emerging from the gravel, and was conducted 1 d/week at permanent stations in the upper reach of the Snake River and 2 d/week in the lower reach. Once a majority of fish were at least 60 mm fork length (FL), additional stations were sampled in each reach for three consecutive weeks. Sampling was discontinued in June or July when the majority of fish had moved into Lower Granite Reservoir.

Passive integrated transponder (PIT) tags (Prentice et al. 1990a) were inserted into fall chinook salmon parr 60 mm FL and longer (Connor et al. 1998). Tagged parr were released at the collection site after a 15-min recovery period. Some of these PIT-tagged parr were recaptured at beach seining stations up to 46 d after initial capture. We calculated growth in fork length (mm/d) for parr as fork length at recapture minus fork length at initial capture divided by the number of days between initial capture and recapture.

Some of the PIT-tagged fish were detected as smolts as they passed downstream in the juvenile bypass systems of Lower Granite and Little Goose dams (Figure 1), which were equipped with PIT-

TABLE 1.—Mean spring water temperatures (°C) measured in the upper and lower reaches of the Snake River and mean spring–summer water temperatures measured at Lower Granite Dam, 1995–1999. Grand mean water temperatures ± SE are also given.

Year and mean	Snake River		Lower Granite Reservoir
	Upper reach	Lower reach	
1995	11.8	10.9	15.0
1996	12.7		15.3
1997	12.4	11.2	14.4
1998	12.0	11.5	15.5
1999	12.3	10.6	
Grand means	12.0 ± 0.2	11.1 ± 0.2	15.1 ± 0.2

TABLE 2.—Mean growth rates (mm/d ± SD) for wild fall chinook salmon parr in the upper and lower reaches of the Snake River, 1995–2000. Sample sizes are in parentheses. The grand mean ± SE growth rates were significantly different (P = 0.003).

Year and mean	Mean growth rate	
	Upper reach	Lower reach
1995	1.2 ± 0.3 (148)	1.0 ± 0.3 (78)
1996	1.1 ± 0.2 (19)	0.9 ± 0.4 (49)
1997	1.3 ± 0.2 (20)	0.8 ± 0.3 (80)
1998	1.1 ± 0.3 (112)	0.9 ± 0.3 (129)
1999	1.3 ± 0.3 (171)	1.1 ± 0.3 (92)
2000	1.3 ± 0.2 (90)	1.0 ± 0.3 (40)
Grand means	1.2 ± 0.04	1.0 ± 0.04

tag monitors (Matthews et al. 1977; Prentice et al. 1990b). We recaptured a subsample of the detected smolts using a diversion device (Downing et al. 2001) located in the fish bypass system of Lower Granite Dam in 1995, and Little Goose Dam from 1996 to 1998. We calculated the growth rate for smolts using the equation described for parr.

Statistical analyses.—We calculated grand mean growth rates by reach and life stage event. For example, grand mean growth rate for parr in the upper reach of the Snake River was calculated as the mean of the six mean annual growth rates for parr in the upper reach. The grand mean growth rate for the parr life stage was calculated as the mean of the 12 mean annual growth rates for parr of both reaches.

We used analysis of variance (ANOVA; alpha = 0.05) with a randomized block design blocking on year to test three null hypotheses: (1) there is

in the lower reach (Table 1). Water temperatures measured at Lower Granite Dam during the spring–summer period were warmer than those measured in both reaches of the Snake River during spring (Table 1).

During the 6 years, PIT tags were inserted into 7,506 fall chinook salmon parr. Of these, 1,028 were recaptured (Table 2). Approximately 80% of the parr used to calculate growth rates were tagged and then recaptured during the spring. Fork length of PIT-tagged parr during shoreline rearing averaged 69 ± 8 mm (SD). Growth rate was significantly higher (P = 0.003) for parr in the upper reach than for parr in the lower reach (Table 2).

In all, 677 PIT-tagged smolts were recaptured at both Lower Granite and Little Goose dams (Table 3). Approximately 99% of these recaptured smolts passed the dams during the spring and sum-

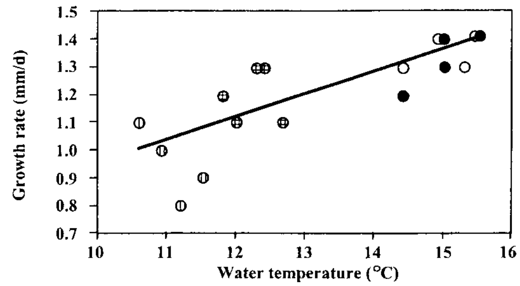

FIGURE 2—The relation between Snake River fall chinook salmon parr (upper reach, vertical and horizontal lines; lower reach, vertical lines) and smolt (upper reach, solid circles; lower reach, open circles) growth rates and water temperature. The regression equation given as: growth rate = 0.184 + 0.077 × temperature (N = 17

parr than the lower reach partly because it was warmer. Parr growth was slower than smolt growth partly because water temperatures during shoreline rearing were cooler than during seaward migration. The smolts originating from the upper and lower reaches of the Snake River grew at approximately the same rates partly because they shared a common, relatively warm migration environment.

Numerous dams were constructed along the Snake River during the 20th century that reduced the potential of the Snake River to support fall chinook salmon. Brownlee, Oxbow, and Hells Canyon dams eliminated spawning and rearing in the most productive habitat near Marsing, Idaho

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in Tables 1, 2, and 3.

nificantly lower (P = 0.002) than smolt growth rates.

Growth rate was positively correlated with water temperature (N = 17, r^2 = 0.62, P = 0.0002; Figure 2).

Discussion

Our study was subject to several limitations. Sample sizes of parr and smolts used to calculate growth rates were small in some cases because of low abundance, difficult sampling conditions, and logistical constraints imposed by the dams. We did not analyze all the factors that affect the growth of juvenile anadromous salmonids. Water temperature was a logical variable to study because it

torical information on the growth rate of Snake River fall chinook salmon, but water temperatures were warmer near Marsing than presently observed in the upper and lower reaches of the Snake River. Spring water temperatures in the Snake River near Marsing averaged 14.2°C in 1961, 14.4°C in 1962, and 13.5°C in 1963 (Connor et al. 2002), which were the last 3 years this reach of river supported fall chinook salmon. Based on our regression equation, these temperatures would result in growth rates of 1.3, 1.3, and 1.2 mm/d compared with the average rates of 1.2 and 1.0 mm/d we observed in the upper and lower reaches, respectively, of the Snake River from 1995 to 2000. Fall chinook salmon parr probably grow more slowly in the upper and lower reaches of the Snake River than they did in the relatively warmer water of the Snake River near Marsing.

ment activities with the potential to decrease growth rates below 1995–2000 levels should be monitored. Releasing large numbers of hatchery fall chinook salmon into the Snake River to supplement wild production might eventually reduce growth through intraspecific competition (e.g., McMichael et al. 1997). Releasing cool water from reservoirs upstream of Lower Granite Reservoir to improve the downstream migration rate and sur-

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